Eawag –
Swiss Federal Institute of Aquatic
Science and Technology

Annual Report 2015

eawag
aquatic research

Aldo Todaro

Eawag, the Swiss Federal Institute of Aquatic Science and Technology, is part of the ETH Domain. This comprises the Swiss Federal Institutes of Technology in Zurich (ETHZ) and Lausanne (EPFL), Eawag and three other independent, application-oriented research institutes – the Paul Scherrer Institute (PSI), the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) and the Swiss Federal Laboratories for Materials Science and Technology (Empa). Nationally rooted and internationally networked, Eawag is concerned with concepts and technologies for the sustainable management of water resources and aquatic ecosystems. In cooperation with universities, other research centres, public authorities, the private sector and NGOs, Eawag strives to harmonize ecological, economic and social interests in water, providing a link between science and practical applications. Just under 500 staff are employed in research, teaching and consulting at the Dübendorf (Zurich) and Kastanienbaum (Lucerne) sites.

Cover photo
Chlorination of pool water leads to the formation of trichloramine, a potentially harmful substance. Fabian Soltermann of the Water Resources and Drinking Water department investigated factors influencing the production and degradation of this unwanted by-product. Here, an attendant at the Wallisellen Water World facility watches as Soltermann (left) tests his new method for measuring trichloramine levels simply and at low cost. (Photo: Aldo Todaro)

Editorial


Aldo Todaro

Eawag invests substantial time and effort to make our work accessible and relevant to Swiss stakeholders, and to support society at large on water-related issues. In 2015, we reached a new level of engagement in the French-speaking region of Switzerland: Eawag's annual Info Day was held in Lausanne, at the SwissTech Convention Center on the EPFL campus. This reflects the strong collaboration between Eawag and EPFL, which has increased significantly in recent years and now includes joint faculty appointments, joint projects, EPFL doctoral students conducting research at Eawag and the Mooc series on "Sanitation, Water and Solid Waste for Development", as well as joint responsibility for the Swiss Centre for Applied Ecotoxicology. As EPFL moves into a transition period in its uppermost academic leadership, we are convinced that the collaboration between Eawag and EPFL will continue to prosper, expanding the opportunities for both institutions to contribute to Swiss research, education and innovation.

New and strengthened capacities for large-scale experimentation

In the 2013–2016 planning period, Eawag has made targeted investments to increase its capacity for large-scale experimentation in the natural sciences and engineering. With the completion in 2015 of its outdoor pond facility (comprising 36 replicate 15-cubic-metre ponds), Eawag has a diverse range of facilities to conduct ecological experiments under realistic conditions. The backbone of the Empa Nest building has also been completed, and Eawag will soon begin the installation of infrastructure for the Nest Water Hub. This will be an important test platform for innovative technologies for wastewater treatment and resource recovery.

Excellent science that benefits society

In 2015, Eawag was simultaneously preparing for its external peer review and initiating work on its Development Plan 2017–2020. This overlap in assessing past performance and planning future activities and investments allowed Eawag to make a strong presentation to the panel of international experts that visited Eawag in January this year, demonstrating our capacity to do excellent science that benefits society. In 2016, Eawag will celebrate the 100th anniversary of the Hydrobiology Laboratory in Kastanienbaum, which was incorporated into Eawag in 1960. In honour of this occasion, Eawag's Info Day in September this year will be held in Lucerne.

Until then, we hope that you will stay in contact with us by viewing our newly designed website www.eawag.ch (launched last June). The new design provides simpler and more intuitive access to Eawag's expertise – in English, French and German. Among other information on our website, you will find the programme for our practice-oriented continuing education (Peak) courses, in which you are welcome to participate. For updates on Eawag's activities throughout the year, you can subscribe to our quarterly electronic newsletter. There's no need to wait for the next Annual Report!

Janet Hering
Director

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Peter Penicka

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Heinz Büscher, University of Basel

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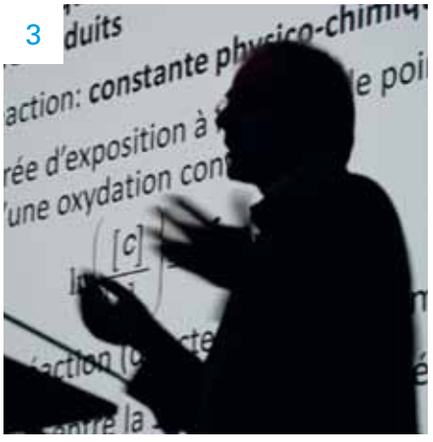

Andres Jordi

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Peter Penicka

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Cable Risdon

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Aldo Todaro

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Chinese Embassy

Highlights of 2015

1 **Pond facility for experiments under natural conditions.** At Eawag's Dübendorf site, an outdoor experimental facility comprising 36 ponds has been built. The facility – the only one of its kind in Europe – will allow researchers to carry out replicable and statistically robust ecological experiments under natural conditions; laboratory results, in contrast, are generally not directly applicable to the environment. In the ponds, researchers will study communities of different organisms in order to understand how genetic diversity arises or biodiversity is maintained, and to identify the environmental factors responsible. Only species found in the catchment of the Glatt river will be used in the experiments.

2 **Fish evolution: the disadvantages of specialization.** In a study published in Science, researchers at Eawag and Bern University showed that numerous cichlid species in Lake Victoria (East Africa) became extinct after developing an evolutionary innovation – a second set of jaws – which enabled them to feed on larger prey. Cichlids with these pharyngeal jaws take several hours to swallow a fish. This put them at a disadvantage when the Nile perch (which can swallow a fish within a few minutes) was introduced around 60 years ago. Faced with this competition, more than 80 cichlid species died out. The study demonstrates the threat which rapid environmental changes pose to highly specialized species.

3 **First Info Day held in French-speaking Switzerland.** To increase engagement with water professionals in French-speaking Switzerland, Eawag's Info Day was held in Lausanne. In view of the new Waters Protection Act, which requires wastewater treatment plants (WWTPs) on surface waters contaminated by micropollutants to incorporate an additional treatment step, the event focused on micropollutant removal measures. The decision to upgrade WWTPs was largely based on Eawag research. The challenges of implementing the legislation were discussed by around 200 experts from the political, administrative, business and scientific spheres. There was broad agreement that, while policy is moving in the right direction, there is a need for further research and improvements in analytical methods. The first francophone Info Day was enthusiastically received in the region.

4 **Lawmakers interested in water research.** The National Council's Environment, Spatial Planning and Energy Committee (Cespe) visited Eawag in August. Eawag Director Janet Hering stressed the relevance of aquatic research for society and the authorities. ETH Board representative Barbara Haering emphasized the importance of continuous, assured funding for research. On a tour of the site, the visitors were informed about various projects: the Blue Diversion toilet and fertilizer production from urine, whitefish diversity, the use of environmental DNA for biodiversity monitoring, and the removal of nitrogen and micropollutants from wastewater. Several participants praised Eawag's consistent efforts to bridge the gap between research and practice.

5 **Major honour for Eawag Director.** In February, Janet Hering was elected as a new member of the US National Academy of Engineering. Membership of the NAE is among the highest professional distinctions accorded to an engineer. The Academy thus honours those who have made outstanding contributions to engineering research, practice or education. During her career, Hering has studied the occurrence and mobility of trace metals and other inorganic contaminants in natural waters and treatment technologies for their removal. At Eawag, she is also concerned with global water management challenges and the interface between science and policymaking.

6 **Platforms to promote knowledge sharing.** Following the success of the Micropollutants Process Engineering Platform, Eawag – in collaboration with the Swiss Water Association (VSA) and the Foen – has established a Water Quality Platform. The new platform is concerned with the challenges involved in assessing water quality in surface waters, with particular emphasis on micropollutants. Its role is to bring together major stakeholders, develop expertise and promote the sharing of experience between research, industry and the authorities. To facilitate exchanges with research, the platforms are housed, respectively, by the Departments of Process Engineering and Environmental Chemistry.

7 **Chinese government award for Yang Yue.** Yang Yue (4th from the right, back row) of the Environmental Toxicology department received the Chinese Government Award for Outstanding Self-Financed Students Abroad. With this award, the Chinese Scholarship Council honours outstanding academic achievements by Chinese doctoral students at foreign universities. In his doctoral dissertation, undertaken as part of the National Research Programme "Opportunities and Risks of Nanomaterials" (NRP 64), Yue investigated the uptake and fate of silver nanoparticles in rainbow trout gill cells.

Supporting society on water-related issues

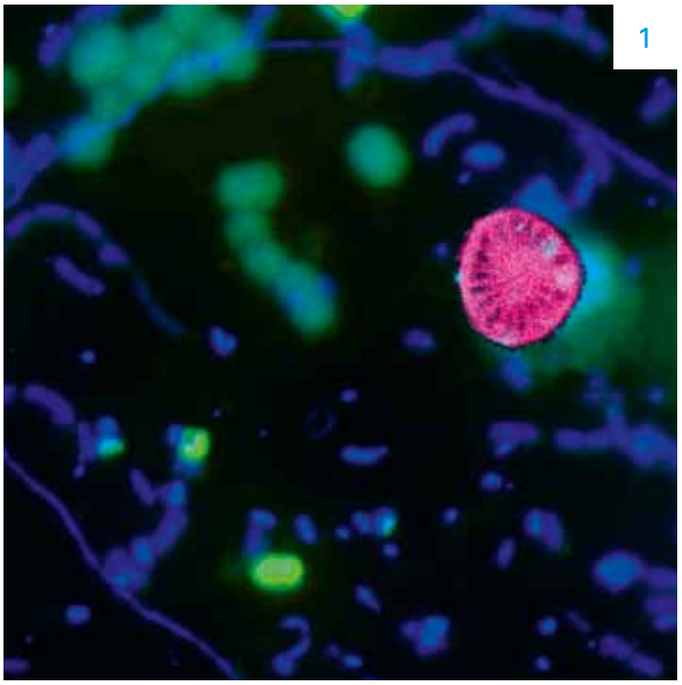
Ecotoxicity testing without animal experimentation: Julita Stadnicka examines cultured gill cells in the lab. In combination with computer modelling, the growth of these cells can be used to predict whole-fish growth. (Photo: Aldo Todaro)

Creating knowledge for practice
Eawag's research is oriented towards issues of practical relevance and challenges facing society. It focuses on water for human welfare and ecosystem function, and on the management of competing demands in the water sector. Researchers at Eawag adopt a systemic approach, seeking to understand processes and relationships at every level – from cell to ecosystem, from natural habitat to full-scale plant.

Inter- and transdisciplinary dialogue
Eawag's research is interdisciplinary and involves engagement with water professionals and authorities. For example, in the "Autarky toilet" project, launched in 2015, process engineers, social scientists and developing-country specialists are developing grid-free, on-site treatment technologies. This project involves collaboration not only with researchers from the Paul Scherrer Institute, EPFL and FHNW, but also with industry partners. Participating in Eawag's "EcoImpact" project (studying the impacts of micropollutants in freshwater systems) are various federal and cantonal authorities, as well as companies and non-profit organizations. As part of the Swiss Competence Centre for Energy Research, in partnership with the Federal Institute for Forest, Snow and Landscape Research (WSL), Eawag is assessing the social effects and the environmental impacts of future changes in hydropower production.

World-class research
Eawag's expertise, valued by water professionals and policymakers alike, is based on excellence in applied research and basic science. Numerous publications in prestigious journals underline Eawag's position as one of the world's leading aquatic research institutes. As regards articles on micropollutants, for example, according to the Web of Science Core Collection, Eawag leads the field internationally in the area of analytical and treatment methods: Eawag scientists have contributed to many of the most-cited publications on this topic. Also reflecting the institute's scientific excellence are the many awards received by Eawag researchers in 2015.

Nationally rooted, globally networked
Eawag researchers contribute their expertise to numerous national and international scientific bodies and committees. For example, Eawag is represented on the Research Council of the Swiss National Science Foundation. In 2015, Eawag Director Janet Hering was elected as a member of the prestigious US National Academy of Engineering. Eawag scientists sit on the advisory boards of around 50 major international journals (including Science).



Eawag/MPI Bremen

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Using a combination of analytical methods (fluorescence microscopy and X-ray spectroscopy), researchers showed that methane-oxidizing bacteria (fluorescent green) occur in close proximity to round diatoms (pink).

Chain pickerel inhabiting near-shore (littoral) areas have an arrow-like body shape and feed on sunfish (left). Those found in open-water (pelagic) habitats are more muscular and streamlined (right). They feed mainly on alewives which have adapted to conditions in landlocked lakes and – unlike migratory alewives – reside in the open waters.

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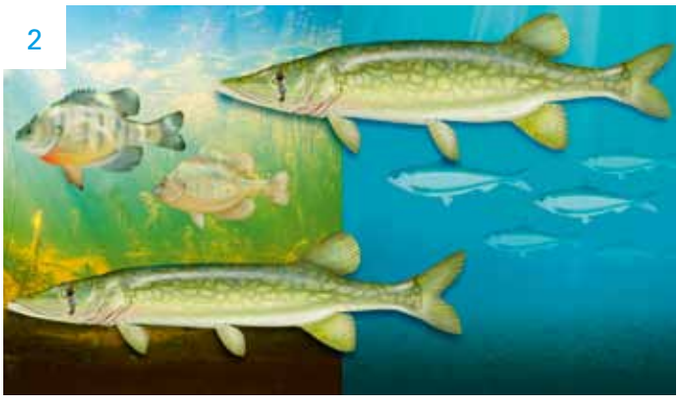

Patrick Lynch, Yale University

Fabian Soltermann

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Equipment used for continuous trichloramine measurement, developed for Fabian Soltermann's doctoral dissertation. Trichloramine levels were found to rise with the number of pool users, but no significant association was detected with urea levels.

1 Methane removal in lakes: a combined effort

Though lakes cover a much smaller area than oceans, they account for a much larger proportion of methane emissions. The gas arises from the degradation of organic material settling on the bottom. Well-mixed lakes are the main sources, while methane emissions from seasonally or permanently stratified lakes with anoxic bottom waters are greatly reduced. It was previously thought that the processes responsible for methane removal in such lakes are the same as in marine systems – oxidation of methane by anaerobic bacteria or archaea. But a study carried out on Lake Cadagno (Canton Ticino) by researchers from Eawag and the Max Planck Institute for Marine Microbiology shows that this is not the case. The scientists demonstrated that methane is almost completely consumed in the anoxic waters of Lake Cadagno, but they did not detect any known anaerobic methane-oxidizing bacteria or archaea. Instead, water samples collected from a depth of around 12 metres were found to contain abundant aerobic proteobacteria. How can these bacteria survive in an anoxic environment? In experiments, methane oxidation was found to be stimulated only when oxygen was added, or when the samples were exposed to light. The scientists concluded that the oxygen required by the bacteria is produced by photosynthesis in neighbouring diatoms. This combined activity only occurs where sufficient light penetrates to anoxic water layers. According to project leader Carsten Schubert of the Surface Waters department, this is the case in most Swiss lakes.

2 In evolving, predators also follow prey

During the colonization of the US East coast around 300 years ago, settlers dammed numerous rivers. Migration of the alewives – which had previously swum upstream from the sea to spawn in freshwater lakes – was thus blocked at many sites. Some of the landlocked lakes are now devoid of alewives, while others harbour descendants of the fish cut off from the sea. Unlike their migratory ancestors, these alewives reside in the open waters, and they also differ genetically.

To study how these changes have affected the chain pickerel (the largest predator found in these lakes), Jakob Brodersen of the Fish Ecology and Evolution department carried out systematic surveys of 12 lakes. These included lakes where alewives could still migrate to and from the sea and landlocked lakes with and without alewife populations. In all cases, chain pickerel occur in littoral zones, but according to Brodersen, "It's only in landlocked lakes with alewife populations that pickerel are also found in the open waters." Analysis of their stomach content revealed that pelagic pickerel mainly feed on alewives, while littoral pickerel prey on sunfish. The body shape of the pelagic pickerel is also adapted to its new habits and habitat, differing markedly from that of the littoral pickerel (cf. graphic).

Barriers impassable to fish also exist in Switzerland. From earlier studies, it is known that hydropower plants, weirs or waterfalls can adversely affect the genetic structure of isolated populations, or even lead to the extinction of a population. To mitigate these effects, fish passes are often constructed. How fish passes affect the genetic structure of populations has now been investigated for the first time by Alexandre Gouskov of the Aquatic Ecology department and co-workers. In a study of the chub, the researchers showed that fish passes have positive impacts on gene flow between different populations; however, they cannot entirely eliminate the effects of barriers.

3 Trichloramine or pathogens in pool water?

Water in public swimming pools is continuously disinfected. However, chlorination leads to the formation of trichloramine, which can irritate the skin, eyes and respiratory tract and may contribute to asthma. This by-product is formed when chlorine in pool water reacts with nitrogenous compounds such as urea. By measuring concentrations in indoor pools, Fabian Soltermann of the Water Resources and Drinking Water department was able to identify factors influencing trichloramine production and degradation. According to his analyses, trichloramine levels mainly depend on the content of free chlorine in pool water.

In some cases, to reduce levels of disinfection by-products, pool water is also treated with UV light. Soltermann found that trichloramine concentrations were reduced by around 50 per cent in the UV reactor of the treatment system, but only by 10–20 per cent in pool water: "The longer the water remains in the pool, the more trichloramine can be produced again." In addition, depending on the particular pool water conditions, UV irradiation can also promote the formation of other problematic by-products, such as nitrosamines.

An effective way of lowering trichloramine concentrations would be to reduce the amount of chlorine added to pool water – but this involves the risk of failing to meet water-quality requirements.

Diversity improves wastewater treatment performance

High levels of biodiversity ensure that ecosystem functions are effectively performed. This is also true of wastewater treatment plants (WTTPs), as was shown by David Johnson of the Environmental Microbiology department and co-workers. Using genetic analyses, the researchers investigated microbial diversity in samples of activated sludge from ten Swiss WTTPs. The number of different strains of microorganisms detected varied from around 200 to over 1000 per plant. In the laboratory, the microbiologists studied the rates at which ten common micropollutants were biotransformed by the various microbial communities. They found that, the more diverse the microbial community in the biological treatment step, the more effectively micropollutants are degraded. The differences in diversity are attributable to different environmental and operating conditions. Optimizing these conditions to increase microbial diversity could thus improve the performance of the biological treatment step.

The reverse osmosis system used by the Californian water utility Orange County Water District (OCWD). When the new wastewater treatment technology was introduced, OCWD consistently used the term "water recycling", thus linking it to a practice which was a familiar part of everyday life – and promoting public acceptance of the project.

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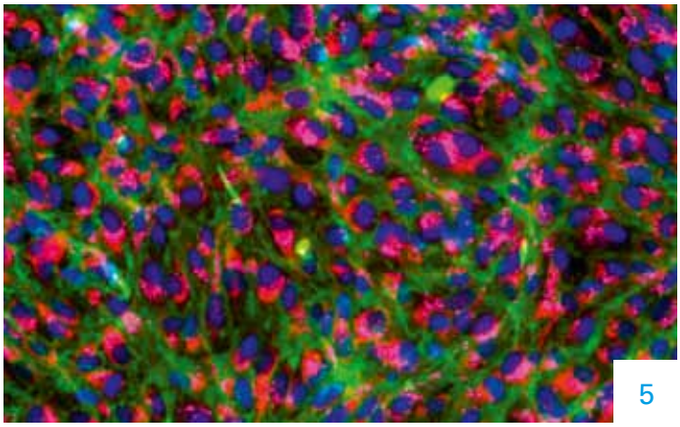
OCWD

Vivian Lu Tan



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Healthy rainbow trout gill cells: nuclei (blue), cell membranes (green), mitochondria (red) and lysosomes (magenta). Toxicology tests using lab-cultured gill cells, combined with modelling, show excellent agreement with data from in vivo tests. It remains unclear whether gill cells can serve as toxicity indicators for all types of fish tissue.

Peter Penicka

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Using video microscopy and automated analysis, Florian Altermatt (left) and Emanuel Fronhofer observe the dispersal of freshwater ciliates in an artificial landscape. The researchers showed that rapid evolutionary changes enable species to spread faster than previous generations.

4 Facilitating adoption of new technologies

Even though California suffers from chronic water scarcity, numerous efforts to introduce systems that enable drinking water to be obtained from reclaimed wastewater have encountered public opposition. What is required to gain acceptance for potable water reuse? To answer this question, Bernhard Truffer and Christian Binz of the Environmental Social Sciences department, together with colleagues at the University of California at Berkeley, investigated the factors responsible for the success of an Orange County Water District (OCWD) project.

Based on in-depth interviews with a variety of stakeholders, the researchers concluded that the water utility's success was explicable in terms of legitimacy. According to this concept, public acceptance of an innovation is based on three key factors: users must be able to perceive the direct benefits it offers, its compatibility with societal values and its potential to become a routine part of daily life.

These points were all addressed in the strategy pursued by OCWD. Not only did the utility invest considerable time and resources in education campaigns, but citizens were able to express their wishes and concerns through representatives on the project's advisory board. OCWD's position was strengthened by its good reputation – it had a 30-year track record of safe and reliable operations. Other measures inspiring confidence were the adoption of stringent testing procedures and a proactive approach to communication when an incident occurred. The project name "groundwater replenishment system" was also well chosen, as the public associated it with the long-established practice of adding freshwater to groundwater to prevent saltwater intrusion into the aquifer.

The researchers emphasize that a legitimation strategy of this kind cannot be directly applied to other projects but needs to be developed in the light of the specific culture, values and history of a region or target group. Truffer concludes: "The authenticity of a project and its initiators seems to me to be one of the most important criteria for a high level of credibility."

5 Toxicity testing with cells instead of fish

Before new chemicals can be approved, environmental risk assessments have to be carried out. Testing currently involves the use of live fish; for example, around 400 fish are needed for a single early life-stage test. In addition, conventional tests are costly and take weeks or months to complete. An alternative method has now been developed by Eawag in collaboration with the ETH Zurich and EPF Lausanne. Rather than being performed in live fish (in vivo), the new tests use fish cells (in vitro) combined with computer modelling. The results show excellent agreement with data from independently conducted in vivo tests.

Cell cultures rather than live animals are now also being used by researchers in the Environmental Toxicology department to study the effects of environmental pollutants on humpback whales. These marine mammals, with an average length of 17 metres, are of interest for research because large amounts of environmental pollutants accumulate in their blubber. In collaboration with Griffith University (Australia), the researchers succeeded in deriving cell lines from these creatures. According to Michael Burkard, "The cell lines will make it possible to assess the toxicological impact of environmental pollutants on whale cells in the laboratory." Initial tests indicate that whale cells from the newly established lines have a lower sensitivity to DDE (a metabolite of the insecticide DDT) than human cell cultures. When the whale cells were exposed to a combination of chemicals, they reacted much more strongly than to DDE alone. This suggests that a mixture of chemicals has a greater toxicological effect than individual substances.

6 Evolution accelerates spread of invasive species

All over the world, invasive animals and plants are spreading rapidly, displacing other species which may provide important ecosystem services or serve vital functions for humans (e.g. breaking down pollutants in water or protecting against parasites). This means it is important to be able to predict the spread of invasive species reliably. Existing predictive models have frequently proved to be flawed, underestimating the speed of range expansions. An important role is played by rapid evolutionary processes: changes can occur within a few generations – in the case of single-celled organisms, within a few days.

Using artificial landscapes and computer simulations, Emanuel Fronhofer and Florian Altermatt of the Aquatic Ecology department were able to track the dispersal of freshwater ciliates in real time and demonstrate the influence of rapid evolutionary processes. Fronhofer reports: "The longer we continued our experiments, the faster the ciliates moved compared to previous generations."

The results of this study, published in "Nature Communications", should facilitate more reliable predictions of the spread of invasive animals, plants and pathogens.

Practice-oriented education and courses

Nathalie Dubois, Group Leader in the Surface Waters department, with a doctoral student, analysing a bisected sediment core. (Photo: Aldo Todaro)

Distinguished young researchers

The education of doctoral students is one of Eawag's main academic activities. In 2015, Eawag scientists supervised around 140 doctoral dissertations. The doctoral students are from 32 different countries; more than a third come from Switzerland and over half are women. In addition, 136 Bachelor's and Master's theses were supervised at Eawag. Students at all levels also benefit from the inter- and transdisciplinary approach to aquatic research. While working within individual disciplines, they learn to adopt a systems perspective. The high quality of the education provided is indicated by the fact that Eawag graduates are highly sought-after professionals on the employment market. In addition, doctoral students regularly receive awards for their work.

Practice-oriented education

As well as supervising undergraduates and doctoral students, Eawag scientists make a significant contribution to the education of environmental scientists and engineers at higher education institutions. Teaching activities are largely based on the experts' own research and also cover niche areas. Particular weight is attached to practical training in the lab and field. In 2015, the teaching commitment amounted to over 3000 hours at ETH Zurich and EPFL, plus more than 1000 hours at other higher education institutions, including universities of applied sciences. Eawag maintains teaching partnerships with various cantonal universities – with Bern in aquatic ecology and social sciences, with Neuchâtel in hydrogeology, with Zurich in biodiversity and environmental psychology, with St. Gallen in innovation research, and with Fribourg and Basel in systems analysis and modelling. Eawag's collaboration with universities of applied sciences is being further intensified.

Knowledge sharing with practice

Eawag is also committed to the provision of continuing education for water professionals. The practice-oriented course (Peak) programme and the annual Info Day communicate recent research findings and promote dialogue between research and practice. In 2015, Eawag intensified its engagement with water professionals in French-speaking Switzerland by holding its Info Day in Lausanne. In organizing continuing education, Eawag collaborates with professional bodies such as the Swiss Water Association (VSA) and the Swiss Gas and Water Industry Association (SVGW). To reach out to professionals in developing countries, it also runs massive open online courses (Moocs).

Giulia Marthaler, ETH Zurich

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Martin Ackermann is presented with the Golden Owl. The award was established by the ETH Zurich Students Association to recognize outstanding dedication on the part of lecturers.

Julian Pleiner

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The UV measurement system can be used to optimize ozone dosing for the removal of micropollutants at the Neugut WWTP.

Peter Penicka

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Eawag alumna Edith Durisch-Kaiser is responsible for projects such as "Wastewater-free Upper Töss", which is to be implemented over a period of 25–30 years: to protect the Töss river and its groundwater flows – one of Canton Zurich's most important drinking water resources – all the wastewater from the Upper Töss Valley is to be channelled via a tunnel through the Eschenberg hill to the Hard-Winterthur wastewater treatment plant.

1 Golden Owl for Martin Ackermann

At ETH Day 2015, Martin Ackermann, Professor of Molecular Microbial Ecology at ETH Zurich and head of the Environmental Microbiology department at Eawag, received the Golden Owl of the ETH Zurich Students Association (VSETH). This award honours lecturers who provide exceptional teaching. Each year, one lecturer per department receives the award.

2 Practice-oriented Master's theses

In 2015, 102 Master's theses were supervised at Eawag. These often form part of larger research projects and have a practical focus, as shown by the following examples.

Conflicts over the protection and use of water resources are increasingly common. For this reason, cross-sectoral instruments are increasingly being applied within integrated watershed management (IWM). As well as various aspects of water management – water protection, hydraulic engineering and water use – these involve additional sectors such as agriculture, spatial planning and industry. In her Master's thesis, Anik Glaus of Bern University analysed the factors that influence acceptance of such cross-sectoral instruments. She conducted a survey on the IWM process in the catchment of the Dünnern, a river in Canton Solothurn. The results show that stakeholders' acceptance is influenced, in particular, by sociopolitical and institutional factors, e.g. public concern and the provision of information by policymakers.

In his thesis, Julian Fleiner of Duisburg-Essen University tested a measurement method developed by Eawag to facilitate monitoring and control of ozonation for micropollutant removal. Testing was conducted at the Neugut wastewater treatment plant in Dübendorf, which operates Switzerland's first full-scale ozonation facility for municipal wastewater. In the Eawag method, measurements of UV absorbance before and after ozonation are used to optimize ozone dosage. Fleiner showed that this method reliably enables ozone dosage to be adjusted as required, thereby meeting the quality goals for micropollutant elimination.

What sediments can tell us about the past is shown by the Master's thesis produced by Rahel Liechti of ETH Zurich. Using various methods, she studied the natural and industrial sources of heavy metal deposits in the sediments of Lake Walen. The highest lead concentrations were detected in layers from the beginning of the 20th century, and a rise in zinc and lead was evident from around 1963. According to Liechti, this increase could be attributable to effluents from industrial plants along the Linth. The subsequent decline is presumably due to the introduction of wastewater treatment plants in the 1960s. In the mid-1960s, arsenic concentrations peaked in the southern part of the lake. This could be associated with the construction of the Lake Walen road, where an arsenic-rich rock layer was exposed and the heavy metal was leached out.

Doctoral studies in a dynamic environment

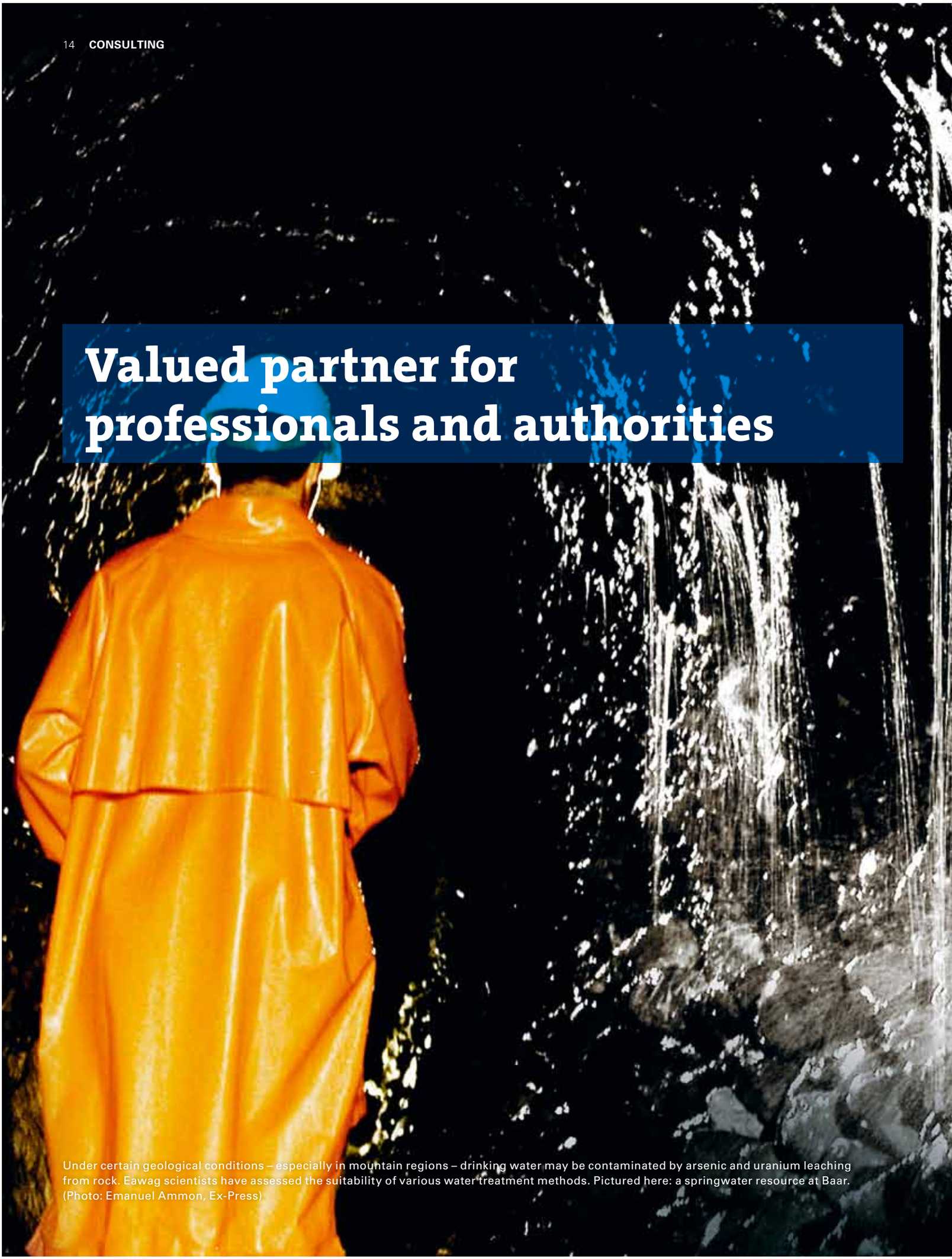
With an excellent infrastructure, specific educational options, such as courses on practical skills for PhDs and specific options and special information events, Eawag offers natural and social scientists and engineers at ETH Zurich, EPFL and other higher education institutions the opportunity to carry out doctoral research in an innovative environment. The arrangements for the selection and supervision of PhD students are designed to ensure that places are allocated to the most talented young scientists, and that they receive optimal support. PhD students at Eawag have their own ombudspersons and are represented on the Staff Council. In addition, the Doctoral Studies Committee provides a forum for their concerns. Events are regularly organized by Eawag to promote close ties among current – and with former – PhD students.

3 Edith Durisch-Kaiser: expertise and social skills

"Even as a child, I was fascinated by water," Edith Durisch-Kaiser recalls. Having left Upper Austria to study Biology and Earth Sciences in Vienna, she pursued doctoral research first at the University of Texas at Austin and then at Eawag, where she specialized in Aquatic Biogeochemistry. After working as a postdoctoral and senior researcher at Eawag's Kastanien to take on a non-research position in the Wastewater Treatment Section of Canton Zurich's Office of Waste, Water, Energy and Air (AWEL). "Not my original field," she admits, with a smile. "I had to learn a lot. But I benefited from something I'd learned at Eawag: a process-oriented approach. Recognizing a problem, understanding the underlying process and thus finding solutions."

Durisch-Kaiser is responsible for a wide variety of projects, including a biological test system for assessing whether micropollutants are effectively removed from wastewater, and a major project to channel wastewater away from the Upper Töss Valley. "What I enjoy about it is dealing with lots of different people. Often I have to advise local authority representatives. Even if conflicting interests are involved, the common denominator is protecting water resources, and we try to find a solution that works for everyone. That calls for social skills just as much as expertise. It's a highly varied and interesting job."

Valued partner for professionals and authorities



Under certain geological conditions – especially in mountain regions – drinking water may be contaminated by arsenic and uranium leaching from rock. Eawag scientists have assessed the suitability of various water treatment methods. Pictured here: a springwater resource at Baar. (Photo: Emanuel Ammon, Ex-Press)

Ongoing dialogue with stakeholders

Eawag scientists collaborate with water professionals in numerous projects and contribute their expertise to national and international bodies. In 2015, for example, they served as experts on around 120 non-academic committees. They offer consultancy services that cannot be provided by the private sector. Through consulting contracts, the latest knowledge and new technologies from Eawag find their way into practice. Eawag had almost 70 such contracts in 2015. By collaborating closely with professional bodies, Eawag promotes dialogue with practitioners; it thus maintains close links with the Swiss Water Association (VSA) and the Swiss Gas and Water Industry Association (SVGW). Eawag is also an important partner for cantonal and federal authorities. For example, Eawag scientists are collaborating with the Federal Office for Agriculture on the Pesticide Action Plan, which is to be available by the end of 2016.

Bridging the gap between research and practice

Various Eawag Competence Centres, including that for drinking water (CCDW), address challenges arising in the water sector. They promote exchanges between scientific disciplines and practice, initiating joint research projects. The Fishery Advice Centre (Fiber) – jointly run by Eawag, the Federal Office for the Environment (Foen) and the Swiss Fishing Federation – provides information on scientific findings and advice on aquatic ecology and fishery management. In 2015, funding for Fiber was secured for another four years. The Swiss Centre for Applied Ecotoxicology studies and assesses the effects of chemicals on the aquatic environment. In an external evaluation conducted in 2015 by experts from academia, industry and policymaking, the Ecotox Centre was highly rated. Following the success of the Micropollutants Process Engineering Platform, Eawag – in collaboration with the VSA and the Foen – has established a Water Quality Platform to bring stakeholders together, develop expertise and promote the sharing of experience between research, industry and the authorities.

Knowledge transfer to practice

The results of Eawag's research are disseminated via user-oriented publications. In 2015, over 60 articles by Eawag scientists appeared in magazines for professionals, such as Aqua & Gas. Eawag also published three factsheets – offering background information and argumentation for policymakers – on the topics of antibiotic resistance, invasive species and microplastics. In Sandec News, Eawag regularly provides information on research projects in developing countries.

Eawag

1

An estimated 300 million people worldwide – particularly in developing countries – use drinking water contaminated with arsenic or fluoride. A new handbook offers guidance on dealing with geogenic contamination. Pictured here: a community filter installed to remove fluoride from groundwater in Ethiopia.

Federal Office for Agriculture Foag

2

Agricultural pesticides are the main diffuse source of micropollutants in surface waters. Thanks to the assessment strategy developed by Eawag, the enforcement authorities now have a standard scientific instrument for evaluating and comparing levels of contamination in streams and rivers.

Andri Bryner

3

As part of her doctoral research, Anne-Marie Kurth developed a new measurement system to assess how groundwater–surface water interactions are affected by river restoration projects. The system takes advantage of temperature differences between groundwater and surface water to determine the direction of flow.

1 Tackling arsenic and fluoride in drinking water

In many regions of Asia, Africa and South America, consumption of groundwater containing arsenic or fluoride as natural contaminants causes severe health problems.

Geochemists, social scientists and engineers at Eawag have therefore investigated how levels of arsenic and fluoride in drinking water can best be reduced. Mitigation strategies and tools developed in cooperation with local partners were tested in two case studies in Bangladesh and Ethiopia. The researchers' experience has now been summarized in a handbook, which is designed to offer practical guidance for authorities, NGOs, planning agencies and engineers. The "Geogenic Contamination Handbook" explains methods of field and laboratory measurement, describes technical mitigation options and discusses how measures can be successfully implemented in accordance with local needs.

Trace elements leached from rock – including arsenic and uranium – may also occur in drinking water in Switzerland. In the revised Food Impurities and Ingredients Ordinance (FIV), the limit for arsenic in drinking water has now been lowered and a limit for uranium has been included. This creates new challenges for smaller water suppliers in mountain regions. In a project supported by the Water Research Fund of the Swiss Gas and Water Industry Association (SVGW), scientists from the Water Resources and Drinking Water department investigated possible treatment methods for arsenic and uranium removal in a commune in Canton Valais. The findings were incorporated in an SVGW Recommendation providing guidance on the management of geogenic contaminants in drinking water supplies.

Ozonation: not suitable for all wastewaters

Treatment of wastewater with ozone gas is an effective method for the removal of micropollutants. However, in the case of wastewater contaminated with industrial or commercial effluents, this process may give rise to transformation products of ecotoxicological concern. According to Urs von Gunten, an environmental chemist who studies micropollutant removal methods at Eawag and EPFL, "If the water contains bromide, for example, carcinogenic bromate may be formed as a result of ozonation." Von Gunten and his team have developed a five-step test for assessing whether or not a particular type of wastewater is suitable for ozone treatment: "The test provides decision support for the authorities as regards the upgrading of wastewater treatment plants." In the coming years, around a hundred WWTPs across Switzerland are to be upgraded with an additional treatment step to reduce micropollutants.

2 Assessing micropollutants from diffuse sources

In wet weather, pesticides can run off into streams and rivers from agricultural areas, while heavy metals and biocides such as wood preservatives enter surface waters from roads and built-up areas. Especially in small and medium-sized watercourses, these diffuse inputs of micropollutants can lead to peak concentrations which clearly exceed legal limits.

But to what extent are Swiss rivers and streams contaminated with micropollutants from diffuse sources? To date, there has been no standard approach for the assessment of micropollutants, which is complicated by the diversity and complex input dynamics of these substances. On behalf of the Federal Office for the Environment (Foen), an assessment strategy was developed by Marion Junghans of the Eawag/EPFL Ecotox Centre and Irene Wittmer of the Eawag/VSA/Foen Water Quality Platform, in consultation with experts from cantonal water protection agencies, industry and federal authorities.

The strategy proposes 48 substances that can be used for an overall assessment. In addition, it provides recommendations on where and when samples should be collected and how the results should be evaluated. For this purpose, chronic and acute quality standards were specified by the Ecotox Centre.

Junghans explains: "Levels of contaminants vary widely according to weather conditions. For this reason, we recommend that composite samples are collected over a two-week period. Very often, it's not possible in practice to obtain measurements with high temporal resolution which also include peak concentrations." Although the risks of peak concentrations cannot be assessed with this pragmatic approach, she adds, it does yield a value that permits assessment of chronic effects.

3 Evaluating the effectiveness of restoration projects

As well as increasing biodiversity, ecological enhancement of rivers can reestablish exchanges between groundwater and surface water. Such interactions are essential to the functioning of aquatic ecosystems, as they control not only the availability of nutrients and dissolved oxygen, but also water temperature and quality.

To investigate groundwater surface water interactions in detail, hydrogeologist Anne-Marie Kurth of the Water Resources and Drinking Water department developed a new measurement system which permits continuous, long-term monitoring.

The method was tested on a section of the Chriesbach river in Canton Zurich before and after restoration. Kurth reports: "We found that, for example, gravel islands can have positive effects on exchanges between groundwater and surface water – the rate of surface water downwelling was increased." She now recommends that these exchanges should be taken into account in evaluating the outcome of restoration projects.

Offering progressive working conditions

Each year, Eawag offers a number of places for apprentices. In addition to vocational skills, the training programme focuses on social skills and self-competence. Pictured here: Trainer Denise Freudenmann (left) with an apprentice in the laboratory. (Photo: Aldo Todaro)

Equal opportunities
Eawag is committed to promoting work/family balance, supporting female researchers and providing career development opportunities for all staff. Flexible working hours and the Eawag-Empa nursery facilitate the organization of professional and family life. For low-income families, Eawag provides support in financing nursery places. As far as possible, employees with illnesses or disabilities are integrated into the work process. The Equal Opportunities Committee ensures that due consideration is given to these commitments.

Successful female researchers
Eawag has a long tradition of supporting female researchers, with the first generation now approaching retirement age. For example, 2015 saw the retirement of environmental chemist Laura Sigg, and a special issue of Aquatic Geochemistry paid tribute to her achievements. Women now account for almost 50 per cent of Eawag's workforce, and the proportion of women in managerial positions is over 29 per cent – above average for institutions of this kind. In 2015, numerous female scientists at Eawag received awards for their work.

Intercultural communication
Eawag is committed to upholding fundamental ethical values and abiding by legal standards, and an internal Compliance Guide was issued last year. In 2015, people from over 50 different countries with a variety of cultural backgrounds were employed at Eawag. A number of events were held to raise awareness of the challenges of cultural diversity and intercultural communication.

Coveted apprenticeships
Great importance is attached to vocational training at Eawag, where 24 apprentices are currently being trained as biology/chemistry lab technicians, administrators or IT systems engineers. The stimulating learning environment and high-quality training make Eawag an attractive employer for apprentices. In its vocational training, Eawag collaborates with industry partners. For example, trainee chemistry lab technicians gain insights into analytical methods and quality control at Coca Cola in Dietlikon (Canton Zurich).

Attractive workplace
Eawag provides an excellent working environment for its employees, with a first-class research infrastructure. The new "Aquatikum" and the outdoor experimental ponds completed in 2015 facilitate research under laboratory and natural conditions. Eawag is committed to sustainable operations, carbon-neutral travel, and 100% renewable power and heat production. The "Aquatikum" facility complies with the Minergie P-Eco energy efficiency standard.

Armin Peter

1

At a booth on Mühleplatz in Lucerne, fish ecologists from Eawag and the Lucerne Natural History Museum provided information on fish migration in the Reuss.

Aldo Todaro

2

Catherine Wagner received the Theodosius Dobzhansky Prize (worth USD 5000), one of the most prestigious awards in the field of evolutionary research.

SCNAT

3

Sabine Hoffmann (third from left) received an early career achievement award from td-net – the Transdisciplinary Research Network.

Broad dialogue

Working visit to South Africa with Federal Councillor Doris Leuthard. Early in 2015, Eawag Director Janet Hering visited South Africa as part of a Swiss delegation led by Federal Councillor Doris Leuthard. The working visit focused on energy and climate policy. For Eawag, it provided an opportunity to prepare the ground for future research collaborations and to explore the potential for new joint projects in the water sector.

National Council's Environment Committee visits Eawag. In August 2015, the National Council's Environment, Spatial Planning and Energy Committee (Cespe) paid a visit to Eawag. On a tour of the site, the visitors were informed about current projects such as the Blue Diversion toilet and fertilizer production from urine. Committee members were particularly interested in applied research activities and emphasized the importance of Eawag's role in bridging the gap between research and practice (cf. page 3).

1 **Eawag participates in SCNAT science tour.** To mark its 200th anniversary, the Swiss Academy of Sciences (SCNAT) toured 12 Swiss towns between June and October 2015, presenting a varied "Research live" programme involving around 150 different organizations. In Lucerne, Eawag's contributions included an information booth on fish migration and a guided tour of the Kreuzbuch lake water treatment facility, organized in partnership with the Lucerne water utility (ewl).

Info Day held in Lausanne. In September 2015, Eawag's annual Info Day was held at EPFL. The event was designed primarily for water professionals in French-speaking Switzerland. It focused on the latest research findings concerning micropollutants in wastewater and, in particular, on the situation in the francophone region (cf. page 3).

Awards

International recognition for research and researchers. The US National Academy of Engineering elected Eawag Director Janet Hering as a new member (cf. page 3). In addition, at the World Chemistry Congress of the International Union of Pure and Applied Chemistry in Korea, Hering received an IUPAC 2015 Distinguished Women in Chemistry award. She was one of twelve awardees selected on the basis of excellence in research, distinguished accomplishments in teaching and leadership in the chemical sciences.

2 Postdoctoral researcher Catherine Wagner of the Fish Ecology and Evolution department received the Theodosius Dobzhansky Prize from the Society for the Study of Evolution. This award (worth USD 5000) is one of the most prestigious in the field of evolutionary research, recognizing the accomplishments and future promise of outstanding young evolutionary biologists. Wagner received the prize for her work on adaptive radiation in African cichlids.

3 At a conference in Basel organized by the Swiss Academies of Arts and Sciences, Sabine Hoffmann of the Environmental Social Sciences department received an Early Career Achievement award for transdisciplinary research (worth CHF 10,000). In addition, Eawag's "Vuna" project was one of the three nominated for the main transdisciplinary research award, which honours science that steps out of the laboratory, engages the perspective of scientists working in various disciplines and often includes non-academic players in the research process.

The Harvey M. Rosen Memorial Award was presented to Elisabeth Salhi and Urs von Gunten of the Water Resources and Drinking Water department for a paper entitled "Process Control for Ozonation Systems: A Novel Real-Time Approach", published in Ozone: Science & Engineering. Together with experts from Water Supply Zurich and other authors, Salhi and von Gunten developed a real-time control system that adjusts the ozone dose during drinking water treatment. The new system was successfully tested for two years in a pilot plant at Water Supply Zurich and has recently been implemented in the full-scale lake water treatment plant at Lengg.

In addition, Urs von Gunten was awarded a fellowship under the Chinese Academy of Sciences (CAS) President's International Fellowship Initiative for Distinguished Scientists. This award honours internationally recognized scientists for outstanding accomplishments in their field. Von Gunten, who conducts research at Eawag and EPFL, is an expert on drinking water treatment and water quality.

Awards for young scientists at ETHZ and EPFL. Doctoral students conducting research at Eawag are closely associated with the Federal Institutes of Technology in Zurich and Lausanne. In 2015, their excellent work once again earned numerous awards. Christoph Moschet of the Environmental Chemistry department received the Otto Jaag Water Protection Prize, which recognizes outstanding doctoral dissertations and Master's theses in the field of water protection and hydrology. Moschet's dissertation was concerned with the assessment of pesticides in Swiss surface waters. Fabian Soltermann of the Water Resources and Drinking Water department received an ETH Medal for his dissertation on trichloramine (a disinfection by-product formed in recreational pool water, which may pose a health risk for indoor pool users). Theodora Stewart of the Environmental Toxicology department was also awarded an ETH Medal, for her dissertation on lead toxicity in freshwater biofilm communities. At EPFL, Yang Yue of the Environmental Toxicology department was awarded the Luce Grivat Prize for his dissertation on silver nanoparticles in fish cells. Yue also received the Chinese Government Award for Outstanding Self-Financed Students Abroad (cf. page 3).

Aldo Todaro

4

As different cultures work closely together at Eawag, intercultural communication was a key topic last year for the Equal Opportunities Committee.

Thomas Lichtensteiger

5

Since 2015, almost the entire roof area of the headquarter building Forum Chriesbach has been used for energy production.

Empa

6

In the Eawag-Empa Nest project, Eawag researchers are investigating ways of reducing water consumption and recovering valuable resources from wastewater. In September 2015, the topping-out ceremony for the Nest building was celebrated by the sponsors – from industry, research and the public sector – and all the partners involved in the project.

Personnel news

Eawag Directorate: two new members. In 2015, the ETH Board appointed Alfred Wüest and Christian Zurbrügg as members of Eawag's Directorate. Alfred Wüest of the Surface Waters department, who succeeds Bernhard Wehrli, is Professor of Aquatic Physics at ETHZ and Professor of the Physics of Aquatic Systems at EPFL and represents the Kastanienbaum site on the Directorate. Zurbrügg, who succeeds Peter Reichert, is a Senior Scientist at Eawag and headed the Department of Sanitation, Water and Solid Waste for Development from 2004 to 2015.

ETH Zurich professorships for Eawag scientists. Martin Ackermann, head of the Environmental Microbiology department, was promoted to Full Professor of Molecular Microbial Ecology. He researches topics at the interface between molecular microbiology and evolutionary ecology. Christoph Vorburger, Group Leader in the Aquatic Ecology department, was appointed as Adjunct Professor.

Equal opportunities

4 **Respecting different cultures.** In 2015, the Equal Opportunities Committee (EOC) focused on the following topics: intercultural communication in the multicultural workplace, the compatibility of professional and family life, and part-time employment options, particularly for men. The question of the "cultural glasses" which every individual brings to the workplace was discussed at various events devoted to intercultural communication. The "Shelters for Science Nomads" exhibition highlighted the mobility which is part and parcel of a scientific career. In panel discussions and at info lunches, staff considered the consequences of this mobility for their personal lives and professional activities. At workshops, external experts discussed ways of dealing with the challenges of a multicultural workplace. As regards work/life balance, one social trend is unmistakable: increasing numbers of men wish to work part-time, but they are still reluctant to take this step. The importance of this issue was emphasized at a "Part-Time Man" event organized by the EOC. Further activities are planned in this area.

Infrastructure

Optimal working environment. Excellence in research depends not only on scientists' expertise but also on the research environment, access to financial resources and the available infrastructure. Eawag seeks to offer its scientists the best possible facilities. In 2015, an outdoor pond facility – the only one of its kind in Europe – was built at Dübendorf to allow experiments to be conducted under natural conditions (cf. page 3).

Environmental management

5 **Exemplary in energy.** At the Dübendorf site, Eawag further increased solar power production on its headquarter building, Forum Chriesbach: an additional photovoltaic system came on line in November. In combination with the existing system, annual capacity is thus being increased to around 100 megawatt-hours. The roof area covered by solar panels has increased from 459 to 619 square metres. In addition, solar collectors used to produce hot water cover an area of 50 square metres. This means that almost the entire roof area of Forum Chriesbach is now being used for energy production.

In Switzerland's Energy Strategy 2050, the Confederation is to play an exemplary role. Eawag is supporting these efforts by promoting the use of public transport. It has taken measures to ensure that employees who live nearby can also benefit from cheaper travel on the regional transport network. This was made available in 2015, filling an important gap in public transport offerings.

Collaboration within the ETH Domain

6 **Innovative technologies in an experimental building.** September 2015 saw the topping-out ceremony for the frame of the Nest building (Next Evolution in Sustainable Building Technologies), attended by Zurich City Councillor Carmen Walker-Späh. The Nest project – undertaken in partnership with Empa, EPFL and Lucerne University of Applied Sciences – involves a modular research building. It consists of a central structure (backbone) and exchangeable residential or office units, where new forms of living and working can be tested, as well as innovative construction materials and energy systems. For example, the "Water Hub" project, led by Eawag process engineers, will investigate water and wastewater recycling systems. The project should also help to refine solutions for reducing water consumption and recovering nutrients from wastewater.

Directorate

Janet Hering
Director

Professor of Environmental Biogeochemistry ETHZ

Professor of Environmental Chemistry EPFL

Rik Eggen
Deputy Director

Professor of Environmental Toxicology ETHZ

Jukka Jokela
Group Leader, Aquatic Ecology department

Professor of Aquatic Ecology ETHZ

Alfred Wüest
Group Leader,
Surface Waters department

Professor of
Aquatic Physics ETHZ

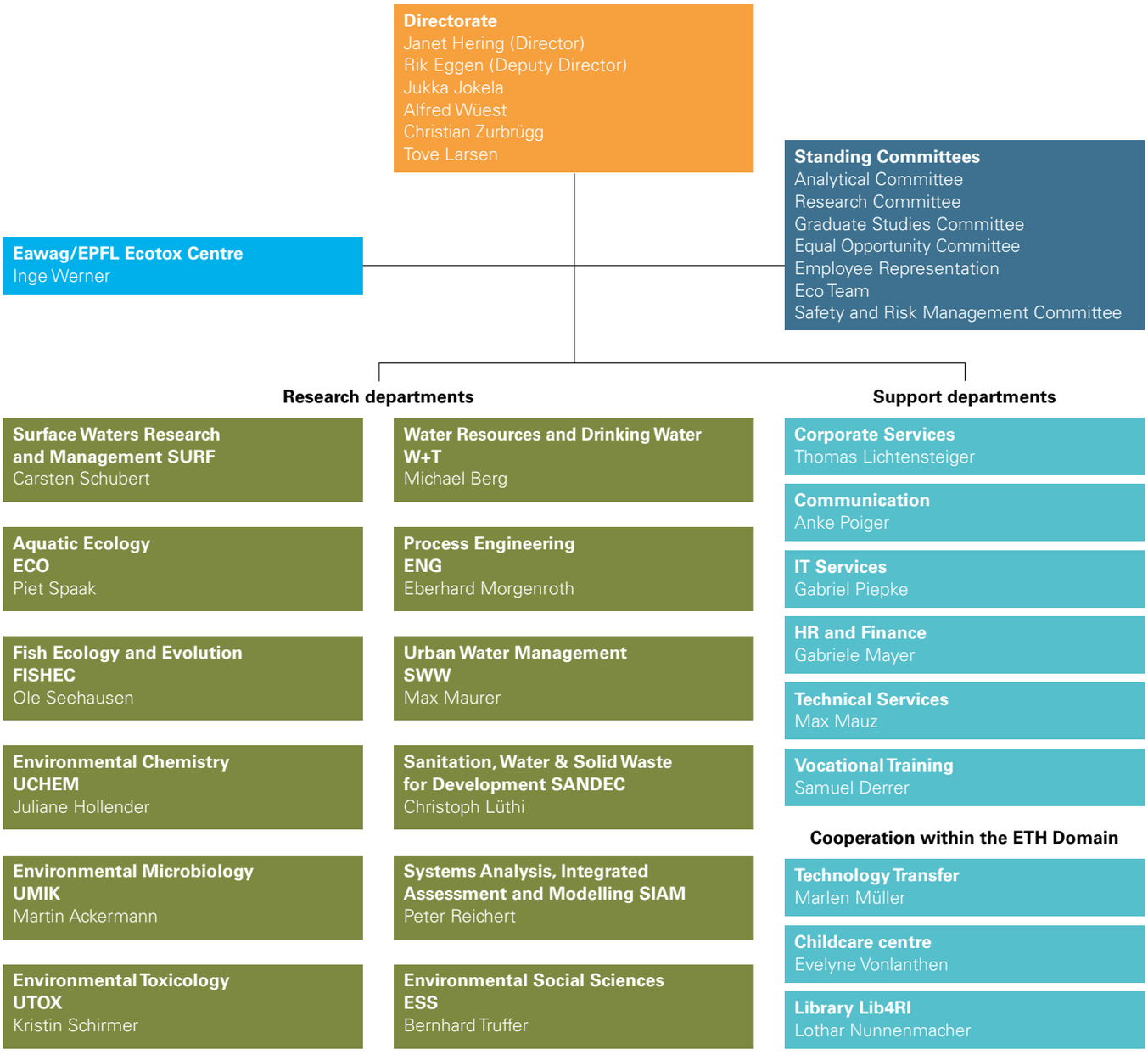
Professor of the Physics of Aquatic Systems EPFL

Christian Zurbrügg
Group Leader,
Sanitation, Water & Solid Waste for Development

Tove Larsen

Group Leader,
Urban Water Management

Organization

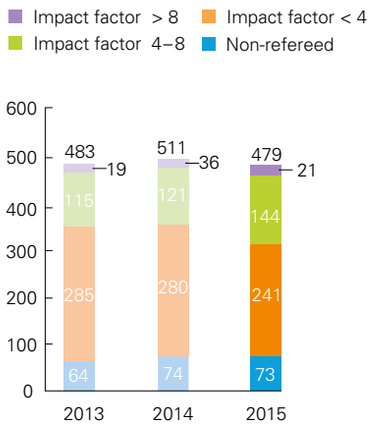


Advisory Board

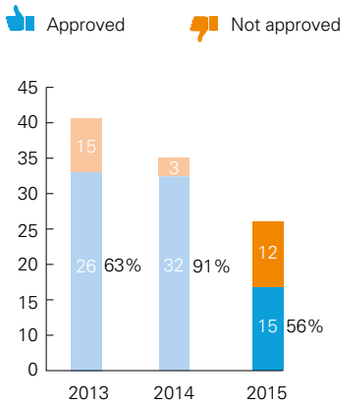
Peter Hunziker, Director, Hunziker Betatech AG, Winterthur
Heinz Habegger, Head of Water and Waste Management Office, Canton Bern
Gabi Hildesheimer, FehrAdvice & Partner AG, Zurich
Michael Matthes, Head of Environment, Safety & Technology, Science Industries Business Association, Zurich
Stephan R. Müller, Head of Water Division, Federal Office for the Environment, Bern
Martin Sager, Director, Swiss Gas and Water Industry Association, Zurich
Reto Schneider, Head of Emerging Risk Management, Swiss Re, Zurich
Felix von Sury, Consultant, Von Sury Consulting, Solothurn
Thomas Weibel, National Councillor, Green Liberal Party, Canton Zurich

Research

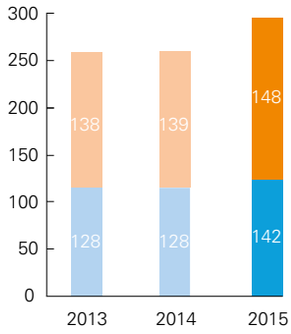
Publications



Swiss National Science Foundation research proposals

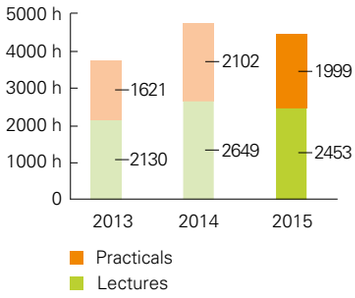


Committee memberships

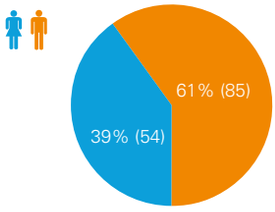


Teaching

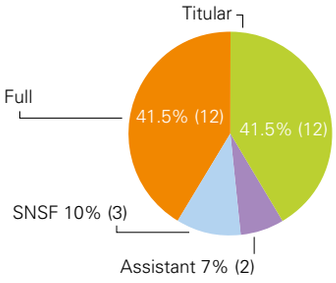
Teaching hours



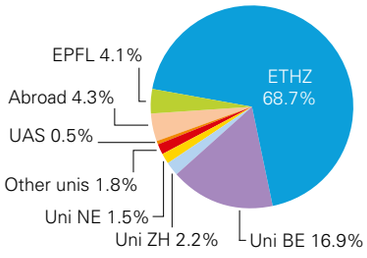
Lecturers



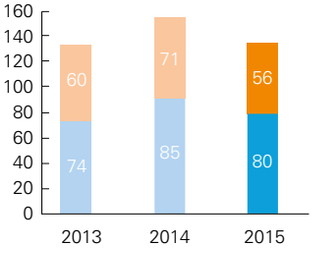
Professorships



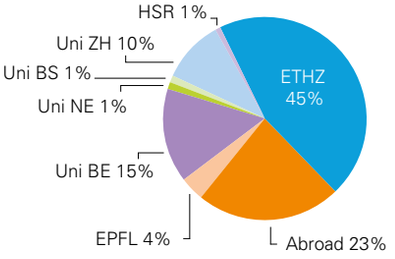
Tertiary-level teaching



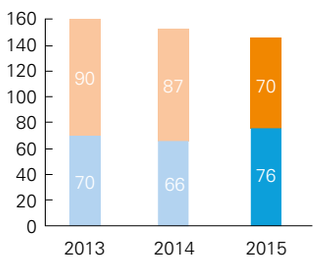
Supervised bachelor's and master's theses



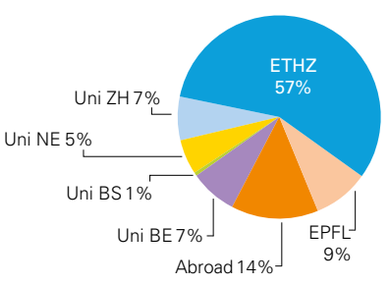
Student home institutions



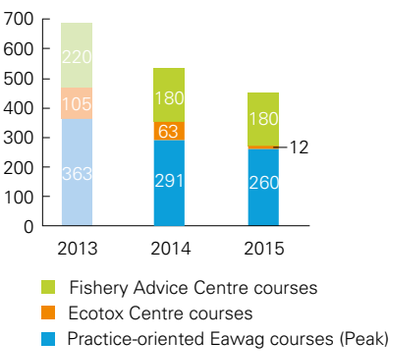
Supervised dissertations



PhD student home institutions



Practical education and training (participants)

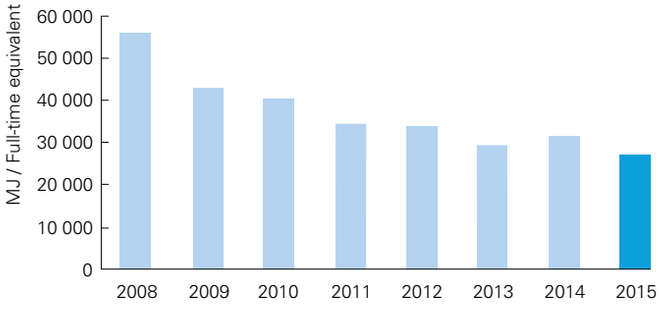


Awards

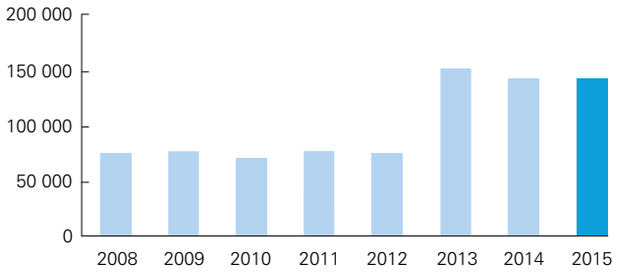
Award	Recipient
Membership of the US National Academy of Engineering	Janet Hering
Distinguished Women in Chemistry 2015 Award, International Union of Pure and Applied Chemistry	Janet Hering
Professorship under the CAS President's International Fellowship for Distinguished Scientists, Chinese Academy of Sciences	Urs von Gunten, Water Resources & Drinking Water
Harvey M. Rosen Memorial Award, scientific journal «Ozone: Science & Engineering»	Elisabeth Salhi and Urs von Gunten, Water Resources & Drinking Water
Early Career Achievement Award, Swiss Academies of Arts and Sciences	Sabine Hoffmann, Environmental Social Sciences
Theodosius Dobzhansky Prize, Society for Study of Evolution	Catherine Wagner, Fish Ecology & Evolution
Rifcon Best Paper Award, Society of Environmental Toxicology and Chemistry Europe	Hannah Schug, Environmental Toxicology
Chinese Government Award for Outstanding Self-Financed Students Abroad	Yang Yue, Environmental Toxicology
Luce Grivat Prize, ETH Lausanne	Yang Yue, Environmental Toxicology
Silver Medal for dissertation, ETH Zurich	Theodora Stewart, Environmental Toxicology
Silver Medal for dissertation, ETH Zurich	Fabian Soltermann, Water Resources & Drinking Water
Silver Medal for Master's thesis, ETH Zurich	Tobias Sommer, Surface Waters
Otto Jaag Water Protection Prize, ETH Zurich	Christoph Moschet, Environmental Chemistry

Environment

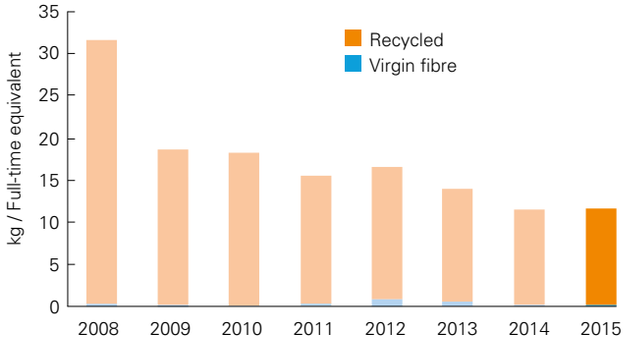
Energy consumption per capita



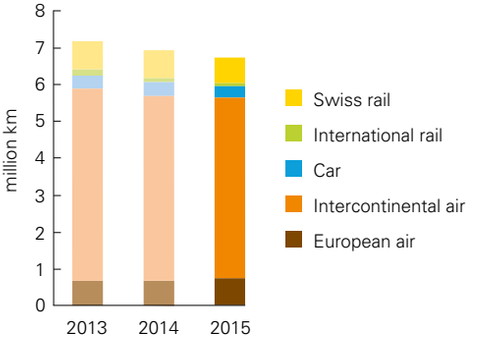
Photovoltaic electricity generation



Paper consumption per capita



Business travel



Finances

Since 1 January 2015, Eawag's financial statements have been prepared in accordance with the International Public Sector Accounting Standards (IPSAS). Financial data and personnel information can be found in Eawag's Financial Report at: **www.eawag.ch/geschaeftsbericht_2015** (document in German)

The Annual Report 2015 presents only a small selection of Eawag's research, teaching and consulting activities. A database of all publications by Eawag researchers (including summaries of articles) is available online at: www.lib4ri.ch/institutional-bibliography/eawag.html. Open access publications can be downloaded free of charge.

The Annual Report is also available in German and French.

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